MEMORANDUM

4/19/2026

TO: Eric Ocegueda, Assistant Professor, Mechanical Engineering
FROM: Apolonio Ordaz, ME 328 – 02
SUBJECT: Lab 3: Stress Concentrations

Overview

The objective of this lab was to analyze stress concentrations in a rectangular filleted bar using both hand calculations and FEA simulations. This was to understand how maximum stress tends to focus on geometric discontinuities and become larger than the nominal stresses.

Background

Stress concentrations occur where there are geometric dissimilarities between a part. At these concentrations, the stress is amplified relative to the nominal stress. These amplified stresses can be calculated using the following equation:

$$\sigma_{max} = K_t \sigma_o \tag{1}$$

Where σ_o is the nominal stress and K_t is the stress factor. K_t can be found experimentally and is usually compiled in charts depending on geometry and load applied. This method of calculating max stress is a very relatively good approximation however, it does not give the exact location of the max stress calculated. For this reason, FEA is used to help locate stress concentrations and better help engineers design to avoid or to utilize such stress concentrations.

Methods

In order to analyze the maximum stress concentration, a rectangular filleted bar was utilized in this analysis. The dimension of the bar follows Figure 1, where the uniform thickness of the bar is 0.5 inches. The two loading conditions applied were an axial force of 5.79 kip, as seen in Figure 2, and an applied moment of 1.67 kip-in, as seen in Figure 3.

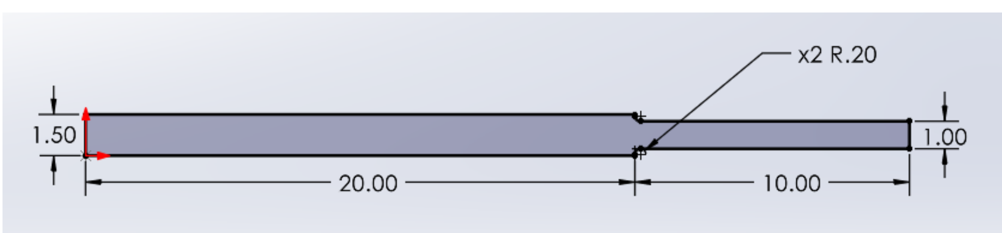

Figure 1. Original Geometry of Filleted Bar with 0.2 in Fillet Radius

When setting up the simulation, the geometry of the filleted bar was recreated. The larger end of the bar was fixed in all directions, while the smaller end remained free. Solid elements were utilized, with a standard mesh of size 0.1 inches. Both applied forces, in all the simulations were applied at the free end of the bar. Hand calculations were performed in order to verify the simulation, at a fillet radius of 0.2 inches, and can be seen in Appendix A. After the initial confirmation of a 0.2-inch filet simulations, a range of filet sizes ranging from 0.4- 16 inches were evaluated in order to analyze the changes in maximum stress. The results of these different radii are summarized in Table 1.

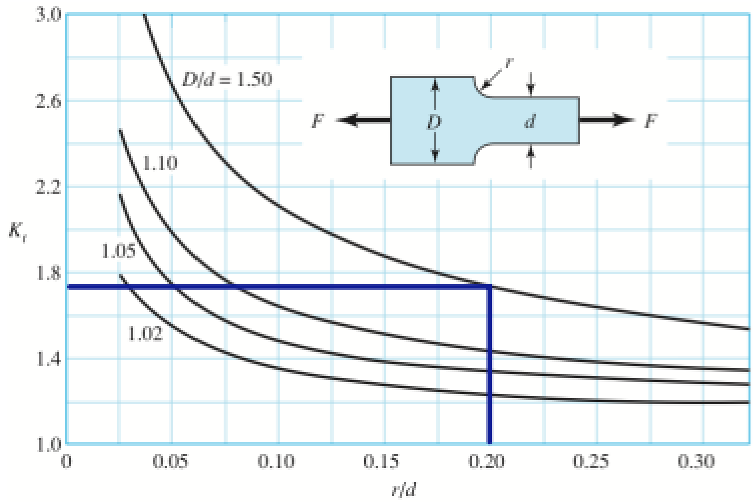

Figure 2. Stress Concentration Factor (K_t) vs. Fillet Radius Ratio (r/d) for a Filleted Bar Under Axial Loading

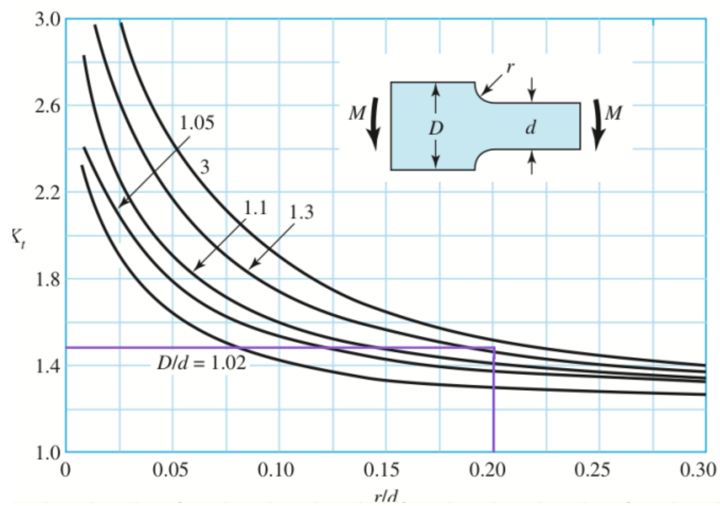

Figure 3. Stress Concentration Factor (K_t) vs. Fillet Radius Ratio (r/d) for a Stepped Shaft Under Bending (Moment Loading).

Results

The FEA results show that stress is not evenly distributed, as expected. The stress concentrations on both load types were concentrated near the fillets, where the cross section changes. These concentrations can be seen in Figure 4 and Figure 5 respectively.

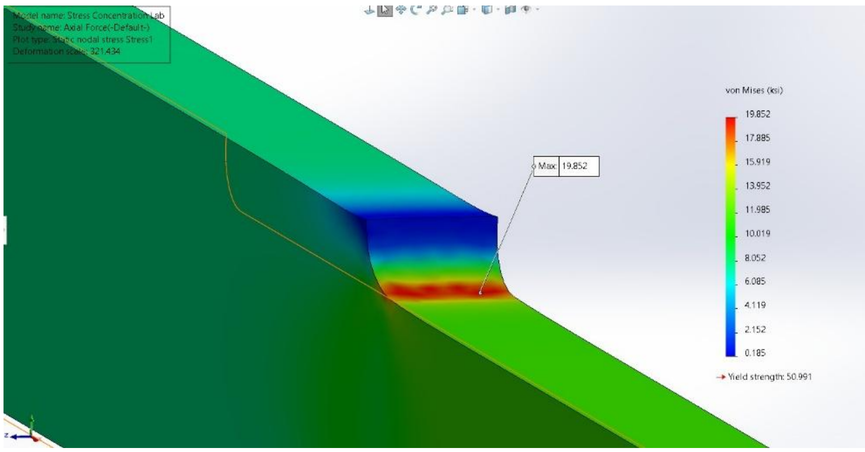

Figure 4. Von Mises Stress Distribution for Axial Loading with 0.2 in Fillet Radius (FEA Result)

The stresses around the axial load are relatively uniform as seen in Figure 4. The large width side of the bar(left) is experiencing relatively the same stress at around 10.01 kpsi, while the smaller width side (right) is also relatively experiencing the same stress at around 8.05 kpsi. Around the fillet there is a visible stress gradient change between the two changing cross sections, as well as the maximum stress point around the base of the fillet.

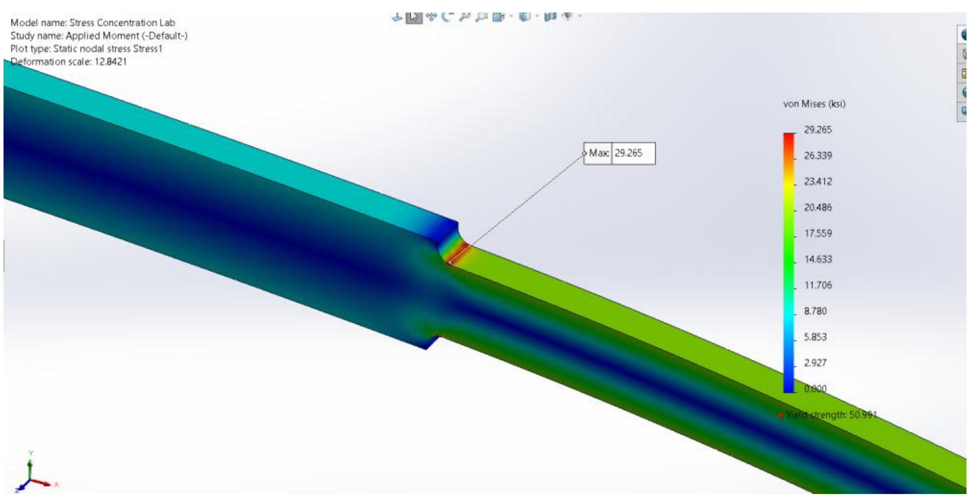

Figure 5. Von Mises Stress Distribution for Bending Loading with 0.2 in Fillet Radius (FEA Result)

The applied moment created a bigger gradient in the bar. As seen in Figure 5 the larger width side of the bar (left) seems to be experiencing much less stresses compared to the smaller width side(right). This makes sense as the moment applied is on the left. It is interesting to note that stress increases further from the axis of the geometric center. Again, it can be seen that the concentration of stress as well as the max stress is at the fillet between the changing cross sections.

Table 1. Maximum Stress from an Axial and Bending load with fillet size

	Load Case	
	Axial Force (1970 lbs.)	Bending moment (1760 Lbs.-in
Radius	Max Stress (kpsi)	Max Stress (kpsi)
0.2	19.85	29.56
0.4	17.66	25.94
0.6	16.19	24.23
0.8	15.34	23.32
1.0	14.80	22.99
2.0	13.30	21.46
4.0	12.89	20.76
8.0	12.85	20.41
16.0	12.80	20.24

In both loading cases it can be seen in Table 1 that the max stresses seem to converge to a value. This makes sense both analytically and intuitively. The smoother the transition between the two widths becomes the more evenly distributed the stresses experienced will be. These phenomena can be seen in Figure 6 and Figure 7.

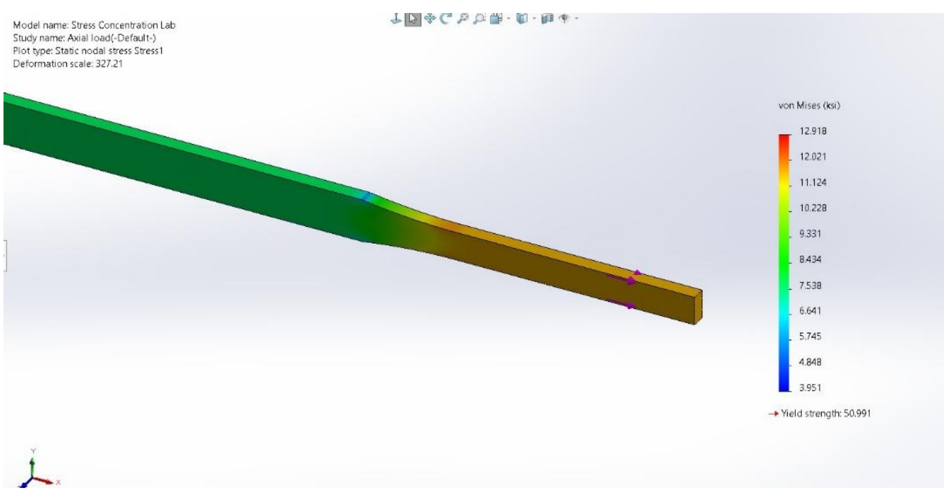

Figure 6. Von Mises Stress Distribution for Axial Loading with 16 in Fillet Radius (FEA Result)

In the case of the axially loaded bar, the max stress of around 11.7 kpsi is uniform on the smaller width side (right). In the case of the applied moment bar, it can be seen that the same is true, which a maximum stress of 20.2 kpsi. The max stress of around 20.2 kpsi is also distributed along the edge of the bar rather than concentrated around the fillet. Also notice that there is a stress gradient in the bar and stresses grow as one move from the middle geometric axis.

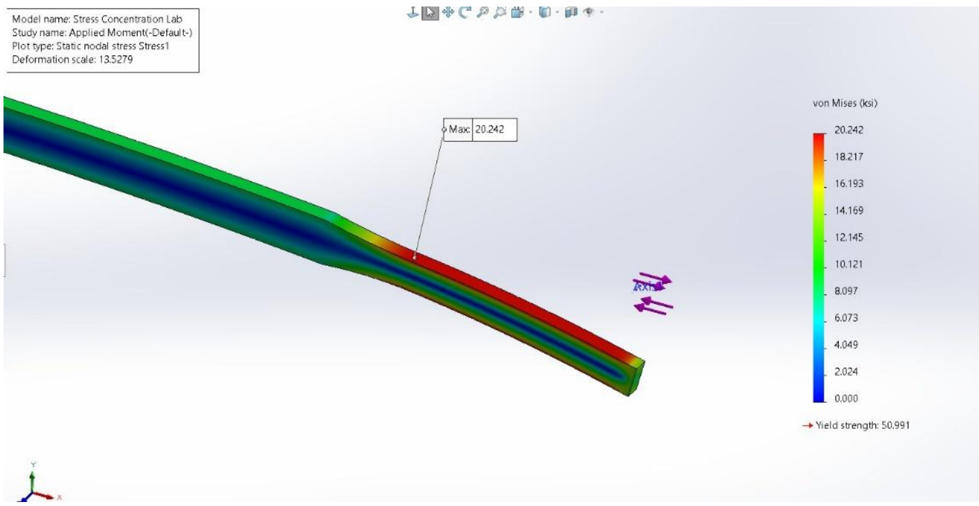

Figure 7. Von Mises Stress Distribution for Bending Loading with 16 in Fillet Radius (FEA Result)

This plateau of stress seems to be around 12.8 kpsi and 20.2 kpsi for the axially loaded bar and applied moment bar respectively. These converging stresses can be explained analytically, utilizing Equation 1. For the axially loaded bar, the K_t value is found using the chart seen in Figure 2. One can see that as the radius gets larger, "r/d" also becomes larger and thus the value of K_t is further to the right. Each line that represents D/d plateau at the end and thus our K_t value converges. The same is also true for the applied moment on the bar as seen in Figure 3. This explains the simulation results found by running FEA.

Conclusion

This lab demonstrates how geometric discontinuities have a large effect on the stress experienced. For the specific filleted geometry analyzed in this lab it is clear that those larger stresses also concentrated at the discontinuity. It can also be seen that as the fillet radii increases, the maximum stress decreases, and the same is true for the inverse. This held true for both the axially loaded bar as well as the bar with the applied moment. It was also discovered that as the radi increase, or the transition between the different widths of the bar becomes more gradual, the maximum stresses plateau and become more evenly distributed. This gives insight and can help one find the ideal radius that strikes a balance between stress management and manufacturing cost. Overall, stress concentrations are important to keep into consideration when making design decisions.

References

Budynas, R.G. and Nisbett, J.K., *Shigley's Mechanical Engineering Design*, 10th Ed., McGraw-Hill Education, 2015.

Ocegueda, E., *Lab 3: Stress Concentrations*, California Polytechnic State University

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Appendix A

Hand Calculations for Applied Axial Force

Hand Calculations

where

$D = 1.5\,in$

$d = 1\,in$

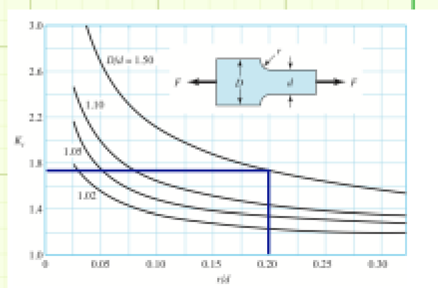
$r = 0.2\,in$

$F = 5.79\,kip$

$t = 0.5\,in$

Figure A–15–5

Rectangular filleted bar in tension or simple compression. $\sigma_0 = F/A$, where $A = dt$ and t is the thickness.



$$\sigma_0 = \frac{F}{A} = \frac{F}{dt}$$

$$= \frac{5.79\times10^3\ lbf}{(1\,in)(0.5\,in)}$$

$$\sigma_0 = 11.58\ ksi$$

$$\frac{r}{d} = \frac{0.2\,in}{1\,in} = 0.2$$

$$\frac{D}{d} = \frac{1.5\,in}{1\,in} = 1.5$$

$$K_t \approx 1.75$$

$$\sigma_{max} = K_t\,\sigma_0$$

$$= (1.75)(11.58)$$

$$\boxed{\sigma_{max} = 20.265\ kpsi}$$

mesh = 0.1

FEA Calculations: $\boxed{\sigma_{max} = 19.852\ kpsi}$

Appendix B

Hand Calculations for Applied Moment

<u>Hand Calculations</u>

wher

$D = 1.5\,in$

$d = 1\,in$

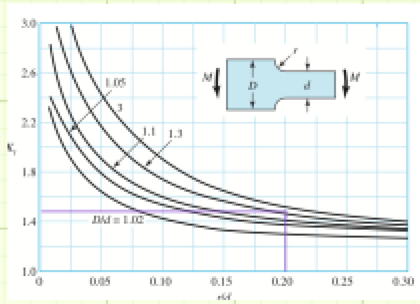
$r = 0.2\,in$

$M = 1670\ lb\text{-}in$

$t = 0.5\ in$

Figure A–15–6

Rectangular filleted bar in bending. $\sigma_0 = Mc/I$, where $c = d/2$, $I = td^3/12$, t is the thickness.



$$\sigma_0 = \frac{Mc}{I} = \frac{12Md}{2td^3}$$

$$= \frac{6(1670\,lb\text{-}in)}{(0.5in)(1in)^2}$$

$$\sigma_0 = 20.040\ kpsi$$

$$\frac{r}{d} = \frac{0.2in}{1in} = 0.2$$

$$\frac{D}{d} = \frac{1.5in}{1in} = 1.5$$

$$k_t = 1.475$$

$$\sigma_{max} = k_t \sigma_0$$

$$= 1.475(20.040\ kpsi)$$

$$\boxed{\sigma_{max} = 29.56\ kpsi}$$

<u>FEA Calculations</u>: $\boxed{\sigma_{max} = 29.265\ kpsi}$